

USAF – Sweden Cooperative Distributed Mission Operations Research

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ABSTRACT: *Both Swedish and US Air Forces have well-established laboratories for conducting research on the effectiveness of Distributed Mission Operations (DMO) systems to enhance individual, team, and inter-team combat skills. The U. S. Air Force Research Laboratory, Warfighter Readiness Research Division in Arizona and the Swedish Defence Research Agency's Air Combat Simulation Centre near Stockholm have entered into a six-year agreement to collaboratively conduct research that will enhance the technologies, processes, and strategies for training based on Distributed Simulation. The goal of this program is to improve both nations' DMO capabilities by sharing expertise in four areas: Measurement and training, Instructional tools, Cognitive modeling for constructive forces, and Coalition mission training research. For all these efforts, specification of the Mission Essential Competencies (MECs) for Peacekeeping Support Operations (PSO) will create a common frame of reference. Measurement and training research focuses on developing and validating techniques for assessing quality of mission performance, communications skills, skill decay, and the training capabilities of different types of simulators within a DMO network. Instructional tools research investigates methods and strategies that enhance the effectiveness of training for local and distributed applications. Cognitive models research is improving the fidelity and utility of computer-generated entities in DMO exercises such as adversary forces and a virtual wingman. Coalition Mission Training Research trials for PSO will integrate and evaluate the products of these research efforts. For these trials, a data link will be established between the laboratories so that US Air Force (USAF) and Swedish Air Force (SwAF) crews can plan, brief, fly, replay, and debrief PSO missions. Mission scenarios, instructional tools, and performance metrics will be derived from the jointly developed PSO MECs. Interoperability will be achieved not only through technical developments but also by using an integrated process to establish training objectives, design scenarios, build a syllabus, and generate evaluation metrics.*

1. DMO Research

The US Air Force (USAF) and Swedish Air Forces (SwAF) are developing Distributed Mission Operations (DMO) systems to complement training in aircraft for selected combat tasks. Research on the effectiveness of DMO conducted at the US Air Force Research Laboratory, Warfighter Training Research Division (AFRL/HEA), and the Swedish Defence Research Agency's Air Combat Simulation Centre (*Flygvapnets Luftstrids Simulerings Center* [FLSC]) has demonstrated that DMO training can enhance warfighter individual, team, and inter-team skills for

tasks that are infrequently practiced due to resource, security, and safety constraints. AFRL and FLSC have entered into an agreement to collaboratively conduct research on technologies, strategies, and tools that will improve each nation's DMO capabilities including coalition training across an international network. While there are several specific objectives for this cooperative research program, the overall plan is to focus on training for coalition Peacekeeping Support Operations (PSO) based on analysis of the Mission Essential Competencies (MECs) required for PSO. Our goal is to ensure seamless interoperability not only

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14. ABSTRACT The Simulation Interoperability Standards Organization (SISO) is dedicated to facilitating simulation interoperability across a wide spectrum. SISO provides forums, educates the modeling and simulation (M&S) community on implementation, and supports standards development. SISO also hosts several M&S conferences including the: Simulation Interoperability Workshop (SIW), the European SIW, and the Behavior Representation in Modeling and Simulation Conference BRIMS. This report contains three papers by the personnel from the Air Force Research Laboratory's Warfighter Readiness Research Division, at the 2006 EuroSIW which was held in Stockholm, Sweden, on 19-22 Jun 2006. The papers are: Paper 1 (06E-SIW-048) - USAF - Sweden Cooperative Distributed Mission Operations Research, by Crane, P., Borgvall, A., & Waldelof; Paper 2 (06E-SIW-050) - International Mission Training Research: Communications and Connection Technologies in a Collaborative Environment, by Greschke, D.A., Zamba, M., Ramo, K., & Waller, B. (this paper won a 2006 "SIWzie" Award); and Paper 3 (06E-SIW-052) - International Mission Training Research (IMTR): Competency-Based Methods for Interoperable Training, Rehearsal and Evaluation, by Bennett, Jr., W., Borgvall, J., Laven, P., Gehr, S.E., Alliger, G., & Beard, R.					
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through technical developments but by an integrated process to develop a complete training program.

1.1 DMO research facilities at FLSC and AFRL

The FLSC is a simulation facility that has been in use for over ten years training pilots, primarily in Beyond Visual Range combat, but also on larger scenario, such as Partnership for Peace operations.

The FLSC simulator system consists of:

- Eight manned Pilot Stations (PS)

The Pilot Stations are not intended to simulate a specific aircraft but rather represent a typical fourth-generation fighter aircraft. The models of aircraft dynamics, sensors, and weapons are all generic parameter-driven models that can be easily adapted to emulate any existing or nonexisting realization of the function. However, the cabin itself and the Man Machine Interface (MMI) including HOTAS are similar to the JAS 39 Gripen aircraft (Figure 1).



Figure 1. Gripen simulator cockpit at FLSC.

Figure 2. F-16 simulator cockpit at AFRL.

Four of the Pilot Stations are equipped with domes with a horizontal field of view of approximately 200°. The remaining Pilot Stations have one to three

projector solutions with a horizontal field of view varying from 40° to 120°. The domes, developed at FLSC, will increase the realism in Within Visual Range (WVR) combat, attack and reconnaissance missions, formation flying, air-to-air refueling, etc.

- Four Fighter Controller positions

These stations simulate the latest version of the Swedish STRIC (Air Defence Center) system, and uses a simulated version of the Swedish tactical datalink.

- After Action Review facilities including God's eye view

The After Action Review facilities includes functions for record and replay of missions, displaying the head down displays, the God's Eye View and adding information such as shooting range, sensor coverage, missile tracks, etc.

- Computer-generated targets and threats

- DIS/HLA compatible interface

- Gigabit network that connects the simulator components.

The DMO research testbed at AFRL includes four F-16C Block 30 Multi-Task Trainers (Figure 2). These cockpits were developed by AFRL as high-fidelity simulators in both physical configuration of controls and displays and functional simulation of F-16 handling characteristics and weapons systems. The Multi-Task Trainers are equipped with AFRL's Mobile Modular Display for Advanced Research and Training (M2DART), which is a full-field of view, rear-projection, dome display system. The M2DARTs provide a 360-degree field-of-regard, out-the-window visual imagery combined with the aircraft's head-up display. These virtual simulators are operated through an observation and control console which is also used to control computer-generated (constructive) forces and a mission recording system. Friendly and adversary constructive entities are generated using the AFRL developed Automated Threat Engagement System (AETS) or the Next Generation Threat System (NGTS). These systems are supported by a distributed brief/debrief system that provides playback of recorded missions together with voice, video, and interactive whiteboard communications with other sites. The F-16 testbed is currently being augmented with four Experimental-Deployable Tactics Trainers, which consist of F-16 cockpits with the same software as the Multi-Task Trainers but reduced functionality focusing on combat skills. The deployable trainers are equipped with three screen out-the-window visual displays.

1.2 DMO research programs at FLSC and AFRL

In addition to the training of pilots, the FLSC is also pursuing research programs in different areas such as tactics development [1], tools and methods for evaluating training [2], and service oriented architecture in a net centric warfare environment. The training evaluation tools and methods include systems for evaluation of the performed missions to provide feedback to the simulation facilities. This ensures the continuous development of the simulator and tools for bringing the result from the simulator to the home base of the training wings. One can then analyze the result of the training week which would provide the possibility of rehearsing the last training before the next training week.

The principal focus of research at AFRL has been development and evaluation of technologies and strategies for enhancing warfighter skills using a systematic approach to training based on specification of MECs and their supporting knowledge, competencies, and experiences. MECs are the “Higher order individual, team, and inter-team competencies that a fully prepared pilot, crew or flight requires for successful mission completion under adverse conditions and in a non-permissive environment” [3]. Defining MECs supports the design of highly focused training programs which provide warfighters with the experiences required to enhance combat skills [4]. One element of the MEC development process is identifying the opportunities warfighters have to gain experience and enhance their skills for each required competency. These training opportunities include academics, simulators, aircraft training using nearby ranges, and large-force exercises. Training gaps exist when the available training medium is not adequate to enhance warfighter skill or occurs too infrequently. DMO serves as one approach to ensuring that all training gaps are filled. MECs also provide a mechanism for evaluating both warfighter performance in the training environment and the effectiveness of the training program [5].

2. Cooperative Research

FLSC and AFRL researchers and engineers are conducting cooperative projects in four areas of mutual interest. Measurement and Training research focuses on developing and validating techniques for assessing quality of mission performance, communications skills, skill decay, and the training capabilities of different types of simulators within a DMO network. Pedagogical Methods research is investigating tools and strategies that enhance the effectiveness of training

for local and distributed applications. Cognitive models research is being conducted to improve the fidelity and utility of computer-generated entities in DMO exercises such as adversary forces and a virtual wingman. Finally, Coalition Mission Training Research, which focuses on Peacekeeping Support Operations, is creating a common frame of reference for participants in both nations and provides a laboratory to evaluate the results of research in the other three areas.

2.1 Performance measurement and training effectiveness research

Work under this area reflect several ongoing research programs at FLSC and AFRL including analysis of communications, assessment of simulator fidelity, and developing metrics to measure skill decay.

Communication Analysis. The FLSC/SwAF has extensive experience with data links and the quality of data link operations and uses. AFRL has experience in developing automated systems for evaluating voice-based communications. Working together, a US-developed automated system for speech-to-text conversion and objective scoring of voice communications based on latent semantic analysis will be integrated with a Swedish developed taxonomy for communication analysis. Sweden’s research on data-based communications will serve as a foundation for AFRL research on incorporating data links into missions previously limited to voice communications. The goal of Communications Analysis research is to identify the communications parameters that are associated with effective mission performance for both voice-only and voice plus data systems.

Fidelity Utility Assessment. Simulator fidelity is frequently viewed as a scalar quality with systems being characterized as having low to high fidelity to actual aircraft or other combat systems. FLSC and AFRL researchers view fidelity as one element in a trade space which also includes cost, physical size, and intended applications. Deployable simulators, for example, have significant size, weight, and power constraints which most likely will limit the visual display system’s field-of-view reducing the pilot’s situation awareness. Force-cuing systems in the seat or stick could mitigate the effect of reduced field-of-view with minimal impact on footprint. Independent and collaborative efforts are being conducted to evaluate the relative effectiveness of training as a function of simulator system and subsystem fidelity level. The goal is to develop metrics and tools which will allow comparisons among alternatives within the trade space

to ensure that a given simulator will meet training needs.

Skill Decay Metrics. Different skills decay at different rates with some being robust and others very perishable without consistent practice. Efforts in this area focus on development of metrics to assess development and decay of knowledge and skills which will serve to define refresher training requirements. When combined with results from Fidelity Utility Assessment, it will be possible to identify perishable skills that can be refreshed using limited-fidelity squadron-based or deployable simulators and which skills require more extensive training.

2.2 Research on pedagogical tools and strategies

The overall objective of this research is to enhance simulator and other ground-based training through incorporation of improved instructional methods, tools, and strategies. This area will develop and validate a suite of tools for within mission and after-action review (debrief). It will also develop and evaluate methods for individual and team training and rehearsal. Included in this evaluation will be an examination of alternative approaches for assessment of constructs such as mission planning, decision making quality, team integration and coordination, situational awareness, picture building and rebuilding, and sensor management. Pedagogical tools and strategies are not limited to simulator-based training. AFRL uses MEC analyses to identify gaps in training and to recommend methods and media that can fill these gaps. FLSC has developed an approach to computer-based training called the Virtual Airbase which provides an intermediary step between books-and-paper academics and real-time simulation. The Virtual Airbase is designed for use at SwAF fighter squadrons to preview skills that will be incorporated in subsequent training events at FLSC and to review previously flown missions. Examples include tactics and radio communications in accordance with standards for beyond-visual-range air combat. Combining MEC analysis to identify opportunities where additional training will be most useful with Virtual Airbase to provide home station training before and after for DMO experience should add to effectiveness and efficiency.

2.3 Cognitive modeling

AFRL and FLSC teams are working to improve the fidelity and tactical realism of cognitive models and

software agents which provide supporting and adversary forces in simulator training exercises. This area involves a variety of activities to capture human in-the-loop tactics and doctrine and to apply the data to the development and improvement of computer-generated forces. It also includes exploration of the practical utility of a virtual wingman concept as a voice-activated mission support agent.

2.4 Coalition training for PSO

The objective of this effort is to install a US–Sweden data link and conduct a program of training effectiveness research exercises on the effectiveness of distributed simulation training to enhance coalition mission skills focusing on PSO.

Networking. The first step is to investigate alternative architectures for data communications that will provide a persistent, reliable, and cost-effective means of connectivity between the FLSC near Stockholm, Sweden, and AFRL in Mesa, Arizona USA [6]. Engineers will study the advantages and disadvantages of each alternative in terms of cost and performance, select the point-to-point data transmission solution that satisfies research requirements and budget constraints of both Sweden and the US, implement the selected course of action, and conduct studies that measure, monitor, and log the performance characteristics of the chosen network topology under and during all research phases and protocols.

Coalition Training Research. The second part of this effort, conducting research exercises for coalition PSO, will serve as a laboratory to evaluate the results of the other collaborative projects. Results from Measurement and Training Research, Pedagogical Tools and Strategies, and Cognitive Modeling development will be integrated into training research exercises. Mission scenarios, simulators with varying capabilities, brief/debrief systems, and constructive forces incorporating enhanced cognitive models will be incorporated into a competency-based training program for coalition PSO.

3. Interoperability through Integrated Tools and Processes

Interoperability for coalition DMO training is not limited to interactions among simulators. Although significant time and resources will be devoted to establishing and testing linkages between the facilities

AFRL and FLSC, additional effort will be required to establish information technology-based tools to support interactions among system developers and participants and, to develop a common framework for developing and evaluating complete training packages. These packages will include mission analysis, developing training strategies to meet specific objectives, syllabus and scenario design for simulator-based training events, evaluating warfighter performance within training events, and assessing the effectiveness of training to fulfill objectives. The central focus of this process will be identifying the MECs and supporting competencies, knowledge, and experiences for successfully conducting coalition PSO [7].

FLSC and AFRL systems developers spend most of the year working over a nine-hour time difference; from March through October, 0800 in Mesa is 1700 in Stockholm. To mitigate the impact of this time difference, US and Swedish researchers and engineers are making extensive use of an internet-based collaboration platform containing functions for discussions, exchanging ideas and opinions, commenting on specific subjects, sharing of documents, calendars for planning and event bookings, and action item lists to keep track and prioritize actions. This web-based platform is available from home or office and adds significant capabilities compared to ordinary e-mail.

Real-time interactions for both system developers and warfighters participating in coalition training research across the Atlantic are supported using video teleconferencing together with electronic, interactive white boards. These white boards allow for interaction between teams working on the same data in separate installations. When planning a training event, for example, teams use a map as background and write concurrently on the screen at the different installations. At the end of the planning session, both parties have agreed upon on a joint plan eliminating misunderstandings and misinterpretations. Combined with briefing slides and data replay, the system also provides for distributed mission planning, briefing, replay, and debriefing.

PSO MECs provide the central focus for Swedish-US collaborative research and coalition training exercises. The purpose of MECs is to identify the high-level competencies required for successful mission completion together with lower level supporting competencies, knowledge, and experiences. Once the MECs have been developed and training gaps identified, cooperative research in the four areas will focus on enhancing warfighter skills and providing experience for these competencies. Performance

measurement and training effectiveness research, for example, will develop methodologies for assessing communications, fidelity utility, and skill decay for a variety of training tasks. Since coalition Peacekeeping Support is a new mission for both the USAF and SwAF, the validity and utility of these methodologies will be assessed in coalition DMO training exercises. Benchmark PSO scenarios will be developed and coalition team performance will be assessed based on success in fulfilling objectives for these missions. Training interventions will be implemented derived from Performance Measurement and Training Effectiveness Research, Pedagogical Tools and Strategies Research, and development of improved constructive entities based on Cognitive Modeling Research. The effectiveness of these interventions will be assessed based on team performance on a second set of benchmark PSO missions.

FLSC and AFRL have entered into the International Mission Training Research (IMTR) cooperative agreement with the goal of improving both nations' DMO capabilities including training for coalition operations across an intercontinental link. Interoperability requires compatible systems, databases, and predictable interactions among simulated entities. In addition, interoperability between research and development teams also requires systems to mitigate the effects of time differences and capabilities for effective real-time interaction. Finally, the IMTR team is working to enhance interoperability by using an integrated process to establish training objectives, design scenarios, build a syllabus, and generate evaluation metrics which will result in more focused research activities and improved training.

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International Mission Training Research: “Communications and Connection Technologies in a Collaborative Environment”

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ABSTRACT: *Both the Swedish and US Air Forces have well-established laboratories for conducting research on the effectiveness of Distributed Mission Operations (DMO) systems to enhance individual, team, and inter-team combat skills. The U. S. Air Force Research Laboratory’s Warfighter Readiness Research Division in Arizona and the Swedish Defence Research Agency’s Air Combat Simulation Centre near Stockholm have entered into a six-year, cooperative research and development project agreement to collaboratively conduct research that will enhance the technologies, processes, and strategies for training based on Distributed Simulation. The goal of this program is to improve both nations’ DMO capabilities by sharing expertise in four areas: Measurement and training, Instructional tools, Cognitive modeling for constructive forces and, Coalition mission training research. In order to enable efforts in any or all of these areas, the infrastructure in which this research is conducted must be designed and implemented based on research objectives across a wide range of requirements. Some of the most significant design considerations for type of training research are: the number of sites; fidelity of the systems to be connected; long-haul secure data and voice communications; scenario development and management tools to be used; exercise and technical management systems to be used; data recording and analysis tools; the communications suites including aircraft and experiment management; planning, briefing and debriefing systems; role-player systems, if any; computer generated force systems (both friendly and hostile); and any requirement to develop blue, red, and/or white force teams. All of these areas significantly impact bandwidth requirements and, in turn, costs to conduct research of this nature. This paper examines the courses of action considered in building the infrastructure necessary to establish the persistent and secure link between the USAF Laboratory at AFRL, Mesa, Arizona, and the Swedish Defense Research Agency’s FLSC at Kista, Sweden, and accomplish the intended research. Historical data for other international distributed training experiments will also be discussed as a baseline for decision-making. Note that some of the final decisions may not have yet been made at the time this paper is presented.*

1. Background

1.1 The International Mission Training Research Objectives

The scope of the work to be done collaboratively between the USA and Sweden is to develop and validate

techniques for assessing aircrew performance in Distributed Mission Training (DMT) exercises including on-line automated measures, instructor rating scales, and off-line analytical tools. These techniques will be used to provide feedback during unit-level training and to develop tools to assess the effectiveness of training with respect to skill acquisition, decay, and retention. Additionally, the

research and development will enhance simulator-based training through incorporation of pedagogical methods, tools, and strategies. These activities will include analysis of Mission Essential Competencies and development of competency-based syllabi, tools for within-mission and post-mission review, and evaluation of alternative approaches for training skills such as planning, decision-making, team coordination, and situation awareness. Furthermore, the research will improve the fidelity and tactical realism of cognitive models and software agents. Activities will include work to capture human-in-the-loop tactics and doctrine and, to apply the data to the development and improvement of computer generated forces. Efforts will also be directed towards exploring the practical utility of a virtual wingman concept as a voice-activated mission support agent. Finally, the two governments will conduct a program of technical research on the effectiveness of training based on distributed simulation to enhance coalition mission skills. This area includes the development, test, validation and implementation of competency-based syllabi and methods for coalition mission training research and the development of a research and training operations protocol to be used in distributed coalition training research events. The partner nations will collaboratively define Mission Essential Competencies for Peacekeeping Support Operations within the context of coalition operations and integration. The purpose of this paper is to describe the design and development process that has been used to date and will be used in the future to build and maintain the long-haul, secure network infrastructure that will enable the accomplishment of the goals of the International Mission Training Research (IMTR) Project Agreement. The network is required to be accredited at the Secret/HEMLIG releasable level. The present period of performance of the IMTR Agreement is through 28 March 2011. The agreement can be cancelled or extended by written agreement of the Parties.

1.2 Distributed Technology Research Efforts to Date at AFRL's Mesa Research Site

The Air Force Research Laboratory's, Human Effectiveness Directorate, Warfighter Readiness Research Division, known as AFRL/HEA and AFRL Mesa, located in Mesa, Arizona, has been conducting local and national, long-haul, distributed training research since the late 1980s. In fact, one of the very first distributed connections AFRL/HEA made even earlier was a hookup over a standard phone line using a 300 baud rate modem that connected the Laboratory in Mesa, AZ, and the Simulator for Air-to-Air Combat (SAAC) Facility at Luke AFB in Glendale, AZ. It wasn't great but it worked. That simple demonstration spawned the R&D that led to the initiation of the Air Force Distributed Mission Operations

(DMO) Program in 1997 and the first networked, multi-ship training center in 1999. Needless to say, the technologies have improved immensely over the last 30 years. AFRL Mesa made the transition from SIMNET (the precursor to DIS) to DIS (Distributive Interactive Simulation) to HLA (High-Level Architecture) throughout the period from the late 1980s until the present.

1.3 Dealing with Latencies over International Real-Time Networks

AFRL Mesa's first international distributed event was a connection to Europe by land line and satellite during Warbreaker 95 using two F-15Cs. The F-15s joined with two F-111 strike aircraft and escorted them to a target area. The exercise was massive and the training objectives for the fighters were obscured by large-scale Command and Control (C2) requirements and technical challenges back then. AFRL/HEA decided to attempt a smaller scale international demonstration involving 8-12 simulators and some constructive threat forces from three different locations in the USA and one in Europe during the Air Force Association's 2000 Annual Convention and Exposition in Washington DC [1]. In Preparation for the Air Force Association (AFA) Show in September of 2000, AFRL/HEA and Thales Training and Simulation (then Thompson Training & Simulation) in Crawley, England, established a Cooperative Research and Development (CRADA) Program to investigate the potential of DMT and other advanced distributed simulation technologies as an additional media for training coalition air operations. This program was known as Project Allied CRAFT (Coalition Research for Asymmetric Force Training). Its goals were to attempt to establish a technical base that would assist the United Kingdom and the United States, as well as their allies, in developing a multi-national simulation network to enhance mission training. Project Allied CRAFT was designed to use the distributed simulation capabilities and supporting infrastructures in the United Kingdom, the United States, and North Atlantic Treaty Organization (NATO) and to grow as these capabilities evolved. Due to severe budget realities in the several years that followed September 2001, the AFA 2000 demonstration was the only event accomplished before Project Allied CRAFT was ended. But during the AFA 2000 technology demonstration, AFRL Mesa successfully networked 2 F-16s and an A-10 at the show site in Wash DC to two F-16 simulators at AFRL Mesa AZ over the Internet, and to two RAF Tornado simulators at Thales in Crawley, England, over an ISDN24 connection. Several real-time demonstrations a day were accomplished throughout the show. The setup worked nearly flawlessly. Other than latencies no doubt introduced by the use of extended routing algorithms in the Internet cloud, there was no

perceptible impact to the execution of the DMT demonstrations including voice traffic using the Internet.

In general, the data packet flow rate between sites during the AFA 2000 show varied, as expected, based on the complexity of the local area network. The total number of entities on the network during each demonstration varied between 95 and 120. The number of data packets per second averaged 400 packets per second (pps) with peaks around 600 pps. The sustained (over a 5 minute period) in-coming bit rate to Washington DC and Crawley UK was recorded at 800 Kbps. This would occur near the end of the scenario each time when most of the entities were engaging and firing each at other or against ground targets. There were occasional peak values of 950 Kbps when numerous simultaneous voice transmissions were made. The ISDN connection between the US and the UK systematic round-trip ping-time was variable and seemed to be dependent on the time of day the phone calls were placed. The average round trip latency between Mesa and Crawley UK ranged from 148 milliseconds during the early morning calls to 198 milliseconds during the calls later in the day. It should be mentioned that there was a 6-hour time difference between Crawley and the AFA show site. The average round trip latency between Mesa and Washington DC over the Internet was 80 milliseconds. As discussed earlier the telecommunications link between Mesa and Crawley England was a primary rate ISDN line. Of the total available lines, twenty channels were used for each session. This equates to 1.28 Mbps. The bit stream was encrypted using the KIV-7HS interposed between the ISDN "modem" and router. Voice traffic between Mesa and Crawley was crystal clear.

Earlier testing in February 2000 highlighted the fact that using fewer than 20 channels of the 24 available resulted in noticeable voice break-up. When using routers, it is also possible, even with full bandwidth available, to begin to experience the effects of buffering when you approach 80% of the total bandwidth. That was why the reduced number of ISDN pairs was a critical item to monitor and is one of its disadvantages. The sustained (over a 5 minute period) outgoing bit rates from Crawley averaged approximately 20 Kbps (1 virtual Tornado + 1 CGF Tornado) with occasional peaks of about 100 Kbps (including voice). The ISDN link-up was very reliable, easy to synchronize, and deemed to be extremely successful. Furthermore, the Internet connection also never failed and was sustained throughout each and every demonstration during the week. The AFA 2000 DMT demonstration was a big success story and confirmed two very important pieces of research data. The first was that the latencies involved in transoceanic connections to Europe were certainly manageable. Data from one other international project just beginning with the Defence

Science and Technology Organization in Australia has shown that given adequate bandwidth over the link (up to 100Mbps), the increased physical distance still only results in a steady round-trip latency of 235 milliseconds [2].

The second discovery made was, aside from some security issues and national security policies in various countries on the use of the Internet, the use of the Internet may one day offer a lower cost alternative for distributed networks used for unit-level ground-based training.

Since the AFA 2000 demonstration, AFRL Mesa has entered into several international coalition government-to-government agreements between laboratories in Australia, Canada, Sweden and the United Kingdom. One of the agreements involving Canada, the UK, and the US called Coalition Mission Training Research, or CMTR, has been active for four years and has produced four major distributed, multi-entity, real-time technology experiments that have helped to define the processes and tools needed to create realistic, immersive training environments; some of which will be discussed briefly in this paper.

1.4 Planning the Infrastructure for International Distributed Networks

So, back to the issue of planning the international connection between AFRL Mesa and the Swedish Defence Research Agency's Flight Simulation Center, FLSC in Stockholm. Experience has shown that when planning a distributed environment, the planning falls into relatively few major categories, regardless of the scale of the environment. The most common categories are:

- Operations and Training Objectives
- Research Objectives, if applicable
- Collaborative Tools to be used
- Assessment Methodologies to be used
- Technical and Engineering Issues and Objectives
- Security Issues
- Bandwidth Requirements
- Budget constraints

While the list of major categories to consider seems simple enough, regardless of the scale of the distributed event, the level of detail (i.e., the number of sub-bullets that end up underneath each of the categories above) will vary significantly from a few to a very large number depending on the extent of the requirements defined by each of the categories. For example, is the scenario large or small in terms of the number of entities? Are there 16 geographically separated sites or only two? Who is the target audience? How big is the database? Does the training audience require training or mission rehearsal

level activity? Do the collaborative tools require real-time transfer of large data files or can it be done before or after the real-time event? Is the event classified or unclassified? Does the infrastructure require time-synchronized playback of the mission files? Does the environment require video-teleconferencing, the use of PowerPoint briefings, and sharing of mission planning files? Answers to questions like these play a large part in determining what is required to satisfy the security and bandwidth requirements. The bandwidth requirement will drive the choices in connectivity that are available and, in turn, affect the cost to establish the connectivity for the planned event. However, the trump card in all of the planning processes to date has been the last category – THE BUDGET! It affects essentially every one of the categories above and the extent to which the technical team can evolve the environment to satisfy all of the desired requirements. Cost is almost always the independent variable. Each one of the categories above is a paper in and of itself, but the focus of this document will be to provide some insight into the last four – technical issues, security, bandwidth, and budget constraints and how those factors are affecting the design of the network to be used for the Sweden-USA agreement.

2. Problem Definition

2.1 Defining the Initial Technical Issues

The team assembled to accomplish the work identified in the Sweden-United States Project Agreement met in Stockholm, Sweden, in October 2005. After the initial mission overview briefings by both countries, the attendees were split into the separate working groups aligned with the major categories of work defined in the Project Agreement. The technical working group was one of the groups. The following major technical issues were identified as needing early attention in the planning process:

- Determine Sweden's policy on using the Internet for connecting government facilities for classified data (the United States allows the use of the Internet using NSA certified encryption)
- If allowed, is the use of the Internet the desired long term solution?
- Is there a CFBL node near the Stockholm facility?
- Which encryption device will be used at each facility?
- Which visual database will be used?
- Will the interactive simulation protocol be DIS or HLA?

- Determine whether or not Sweden can be loaned a US encryption device
- Prepare and be ready to exchange facility accreditation paperwork
- Establish initial connection using routers and the router security encryption scheme, 3DES
- Conduct Ping testing to establish network characteristics and quality of service to be expected
- Integrate COMSEC devices into the network
- Integrate firewalls, filters and intrusion detection devices as required
- Test voice communications first before simulation devices
- Test all collaborative tools
- Complete permission process to connect at a classified level
- Complete the classified connection
- Conduct comprehensive testing process between sites
- Declare network ready for operations

Not all of these technical issues above will be discussed in this paper. The primary areas of interest for this paper are the choice of DIS or HLA, choosing a network backbone to be used for this research project, the database issue, and the security issues to include information security procedures, communications security (COMSEC) procedures, and COMSEC equipment. As stated earlier, budget issues most often drive the extent to which you can define the capability of the infrastructure you are responsible to build. This project is no exception.

2.2 Selecting the Interoperable Protocol – DIS or HLA?

DIS or HLA? The age-old question. It is not the purpose of this paper to advocate a choice of one over the other as the "preferred method." What is true is that throughout the world you will find a mix of everything under the sun from legacy systems that are stand-alone, to 20-year old DIS-based systems, to proprietary protocols to HLA translators, to DIS-based systems using DIS-to-HLA gateways, to true native HLA solutions. As noble as it is to declare "a standard," budgets and the reality of what exists at the moment most often shape the solutions that are both doable and affordable. The good news is that about every combination of interfacing has been experimented with and, in most cases, successfully employed. The challenge is to find the right solution to make whatever combination is chosen work – in real-time. The technical discussions have been centered on what can be done in the amount of time available, with little change to the actual hardware, and with the money that is available.

AFRL Mesa has the ability to do both DIS and HLA. However, DIS has been the default protocol due to its maturity for real-time systems and the depth of experience with its use. The FLSC facility has multiple reconfigurable simulators that use an in-house developed communication protocol based on UDP/IP and TCP/IP as the transport layer. The data is exchanged directly between hosts over the LAN using a proprietary protocol called T3Sim. The host data is converted to “public” data

and is sent to the LAN through a T3Sim-to-HLA gateway using the RPR-FOMv2d17. So, in that context, the LAN at FLSC is HLA 1.3. If HLA is the choice, then agreements have to be made on the choice of RTIs and FOMs. It is true that commercial products are quickly blurring the differences and making the use of multiple RTIs and FOMs possible without less engineering required to make it work. The three options considered by the technical team are shown in Figure 2.1.

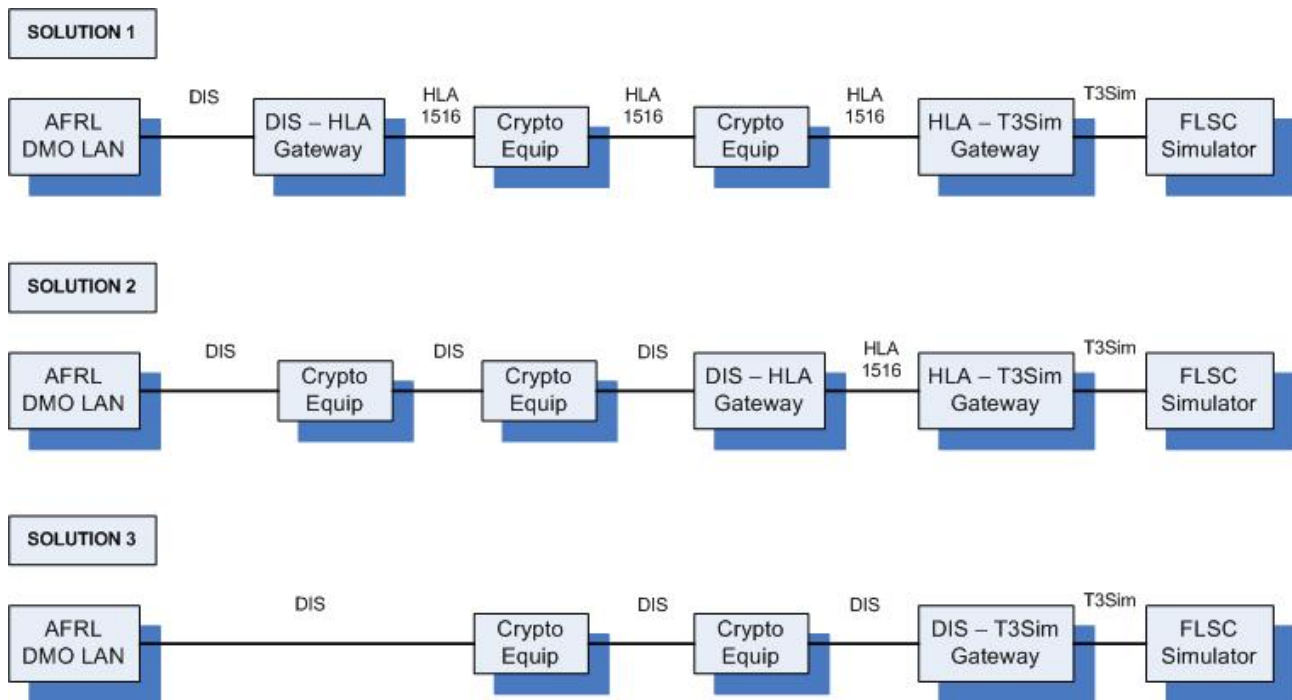


Figure 2.1. Three gateway protocol solutions that are being considered.

One of the strong points that came out of the development of HLA was the FEDEP process. Originally consisting of five steps, then expanded to six, the FEDEP provided a framework in which to define exactly what the Battlespace was going to look like and formed the basis for agreements between objects as to interactions and object descriptions [3]. However, depending on the complexity of the environment you are building, the FEDEP process can involve a significant amount of time. This is more often true when connecting disparate environments for the first time. As is usually the case in coalition environments (between continents), it is more difficult and costly to travel routinely back and forth to each other’s facilities to accomplish in-depth coordination and testing required to accomplish the FEDEP process correctly. Another factor that was considered in making a choice between the three solutions shown in Figure 2.1

was the amount of time it may take to “debug” the interoperability issues when connecting for the first time using a T3Sim-to-HLA and a DIS-to-HLA gateway process. If Solutions 1 or 2 were chosen, no less than three applications would have to be up and running prior to any simulation data flow – the T3Sim-HLA Gateway, the HLA-DIS Gateway, and the RTI; thus, creating a relatively complex solution for a rather trivial problem and making debugging more of a challenge. In DIS, for example, it is common practice to attach a colored beach ball to any entity state PDU that is not recognized in a lookup table of models. This provides a quick visual cue that someone has something wrong. If the subscription or prescription rules or the object definitions are incorrect, one may not see the result of the error at all. Therefore, because of the limited time and money available to each organization, the in-depth experience AFRL Mesa has

with implementing DIS solutions, the ease of debugging problems in a DIS environment, and the very distinct advantage FLSC has by having the aircraft manufacturer as joint venture partner for software development, the decision at this point is to use DIS as the protocol for the first experiments – Solution 3. Since FLSC uses a version of the RPR FOM in their current T3Sim-to-HLA gateway, they have adequate knowledge of DIS and its structure. Furthermore, the T3Sim protocol was developed by their joint venture partner; therefore, developing the T3Sim-to-DIS gateway has very little risk. It is still a goal to conduct the later experiments using HLA.

2.3 Considerations in Choosing the Network Backbone

When establishing LAN environments (not WAN), for simulation, it is essentially true that bandwidth is not a factor. Even with just 10BaseT, you can load the LAN up with hundreds of six degrees-of-freedom (6-DOF) entities, video streams, and voice transmissions and everything works just fine. The default now, in most installations, is probably 100BaseT, so the situation just gets better. Today, Gigabit Ethernet is becoming more common so the possibilities are seemingly endless. In the case of the LAN, costs are down and capability is up. However, when you are ready to open a portal or gateway and begin operating across a wide area network, the rules change. Cost versus bandwidth and quality of service stand right there in the way of “We want everything” requirements. Today it is easy for the “Techies” to say that “Anything is possible.” Technology has solved almost every network-related challenge that ground-based training requirements have presented. But, not every “possible” is affordable. Over the years, AFRL Mesa has used about every combination of commercial land lines for data transmission that is possible. Today, the facility at Mesa has four different dedicated paths to key installations or networks that involve Warfighter readiness research – the Internet, the USAF DMO Portal (an ATM-based system), a T-1 line, and ISDN24 lines. Each has its own dedicated gateway from the Distributed Mission Operations Testbed LAN to the WAN. The cost per month for each of these combinations varies significantly with some having unlimited use and some having a use rate associated with them. It is not the intent of this paper to describe in detail the pro and cons of each type of transmission connection and the exact cost of each. For one, competition and deregulation has made fixed pricing and sole providers a thing of the past. For another, the prices for an existing line from the same company have also begun to drop. For example, the cost of the dedicated T-1 line AFRL Mesa uses to connect to the DMOC at Kirtland AFB, NM, has dropped from 1,250 USD a month to 850 USD. An ATM line point-to-point may cost as much as 9,000 USD a month depending on the distance between addresses. Using ISDN lines

certainly lowers the monthly recurring cost (very inexpensive) but involves use rates that are associated with the bandwidth (number of line-pairs multiplexed together) being used making a week-long overseas connection quite expensive (80,000 to 100,000 USD) [3]. The cheapest, of course, is the Internet. It cost nothing except the cost to connect to some type of Internet Service Provider (ISP) function. Using the Internet also presumes that “the last mile” connection to your facility has sufficient bandwidth to accomplish the objectives of the event being planned. So, each situation has to be evaluated on its own merits based on the bandwidth required, the network configuration desired (e.g., star, ring, grid), the length of time the connection will persist, and, most importantly, the budget that is allocated to the WAN connection.

In the case of the Sweden-US project, budgets are limited so that was a factor in deciding which backbone to use. It was also recognized that due to the normal workload for each facility, the number of recurring long-haul IMTR events per year would be low. Therefore, since the information security policies in both countries allowed the use of the Internet, the decision (at the time this paper was written) is to use the Internet for the point-to-point connection between FLSC and AFRL Mesa.

2.4 The Database Issue – Out-the-Window and Sensor

Databases present the next biggest problem besides budgets. Everyone has one and they are almost always different. While interoperability and compatibility issues have improved over time, we are still not at the point where everyone owns some industry standard form of source data for what becomes the out-the-window (OTW) database file in the run-time configuration. If you listen to the marketing personnel, there is no problem. Experience says otherwise. This paper offers no neat and clean solutions, either. The problem is not confined to just the source data for a database. The fidelity of the database has to be defined using some standard measure, or more correctly some “agreed upon” measure, such as “x meters of resolution imagery” or the DTED level of the terrain skin. After agreeing upon the resolution of the imagery, the size of the database has to be defined in geocells, kilometers, or square miles. After deciding what kind of database satisfies the training or research requirements, it is necessary to evaluate the image generators being used at each site to ensure that they are capable of producing the desired resolution at a real-time frame rate, whatever that is to each installation. It makes a big difference if the texture maps are geo-specific versus geo-typical or just polygon-based man-made texture maps. For the purposes of immersing the participant deeper into the environment, AFRL Mesa has converted completely to geo-specific, photo-realistic

databases. The use of photo-specific terrain texture maps has somewhat reduced the problem of database correlation. It is important to have near perfect correlation so that each simulation system sees the same results visually (and with sensors, if employed) and it is significant when the objects on the ground are intended to be struck with weapons fired or dropped from the air. Integration testing should always include simple target and terrain correlation tests whereby by a system from each site flies to the exact same point in the database to verify the target is at the right coordinates or the tank is at exactly the same intersection etc.

None of the above discussion addresses the sensor correlation and material coding challenges that exist currently. This project won't solve that issue either. Sensor correlation is heavily dependent on the fidelity of the simulation code representing the sensing device. That is to say, one can "fake it" by turning a daytime color OTW scene into a green monochrome scene for night vision goggles or an IR/FLIR sensor simulation, or you may have a physics-based sensor simulation that depends on having values for material code, radiance, reflectance etc. If it is the latter, this is not easily solved in a collaborative environment. Building a database that has material coding at the Texel level is expensive and usually involves licenses of some kind. There are some automated systems that are using LandSat color data to rapidly generate close approximations for material codes, but that process is also not free and does not satisfy a physics-based system. So, for this project, the decision has been made that each facility is on its own for material coding information and implementation of sensors. For the OTW data, the initial scenarios will be based on operating over ranges in the Southwest United States. AFRL Mesa was granted permission by the National Geospatial-Intelligence Agency (NGA) to release the data necessary for Sweden to build a photorealistic database of that area. Follow-on R&D efforts will continue to attempt to develop other common databases in which to develop scenarios.

3. Information and Communications Security Issues

As AFRL Mesa transitioned from classified local and national US-only distributed simulation events to classified multinational, coalition events, an entirely new set of policies and procedures associated with information and communications security have had to be dealt with. For some country-to-country relationships, there are existing technical exchange agreements such as The Technical Cooperation Program (TTCP) which is an umbrella agreement for the exchange of data up to Secret between the English speaking countries. There are also

many agreements that fall into what are called Technology Research and Development Project (TRDP) Agreements that approve specific instances of research efforts defined separately within each TRDP. There are also relationships formed under the auspices of the NATO and its policies and existing agreements between member nations. However, regardless of the pre-existence of any of the umbrella agreements described above, the information security and international affairs systems in each country usually require a separate and distinct Project Arrangement/Agreement and/or a formal Memorandum of Agreement or Understanding (MOA/MOU) for each specific project relationship. This is a process that usually has a very long lead time and is a process that has to be started at the very onset of a collaborative, international, classified or unclassified project with no guarantee of it being approved. While it may be the perception that the United States probably has the some of the most restrictive and comprehensive security policies of any country, AFRL Mesa has found that if the homework is done completely and correctly and with sufficient lead time as to not declare "an emergency," the chances of getting approval for an international collaboration project are good. Fortunately for this project, a TRDP already existed between the US and Sweden that was signed in April of 1997. This clearly reduced some of the "up-front" work that would have been necessary to gain approval. We simply had to write a separate Project Agreement concerning International Mission Training Research (IMTR).

In dealing with the processes associated with Information and Communications Security/Assurance, the major moving parts are:

- Level of classification desired
- COMSEC equipment to be used
- Facility accreditation
- Country-specific security policies and procedures
- Information and Communications Security

From the outset of the planning process, both AFRL and FLSC have agreed that, in order to preserve the highest degree of realism for the operational aircrew who will participate in the IMTR events, the project should be conducted at the SECRET/HEMLIG releasable level. That remains the objective and the Project Agreement for IMTR was approved with that requirement written into it.

3.1 The US Perspective

The existence of an agreement that approves a project between governments with a requirement to exchange classified information does not presuppose that permission to do so has been granted. The existence of the agreement simply provides each party with the proper

authority to seek approval to actually exchange classified information and what information is acceptable to exchange. On the US side, there are several principal agencies that are actively involved in the approval to operate at the classified level with Sweden. They are the AFRL Foreign Disclosure Office, who guides the project requestor through the process, the Air Force Security Assistance Center (AFSAC), who is intimately involved in how to write a PA and the approval of the underlying Project Agreement itself, the Secretary of the Air Force, International Affairs Division (SAF/IA), who ultimately issues the approval to disclose or exchange classified information, and the National Security Agency (NSA), who controls and approves the use of any COMSEC equipment such as the encryption devices, the data transfer devices required to load the encryption devices and the international/allied keymats used to key the COMSEC equipment used in coalition environments. For this project, AFRL Mesa has submitted a request to SAF/IA and the NSA to seek permission to loan Sweden a KG-175 TACLANE encryption device. The type of device that is used depends on the type of transmission backbone you choose for the long haul network. When it has been approved to use a piece of US COMSEC equipment, the procedures require that the equipment and associated support devices be shipped directly to an office that is called the National Distribution Authority (NDA) in the receiving country. A cognizant government official from the approved project then goes to the NDA to sign for and receive the COMSEC equipment. When the need for the COMSEC equipment is done, US policies require the immediate return of the COMSEC equipment to US control which begins with its return to the NDA and then back to the NSA. Without an NDA office in the partner country, approval for use is not granted. At the time this paper was written, an NDA did not exist in Sweden. However the process to establish an NDA had begun independent of this IMTR Project. It is anticipated that in the time it takes to approve the loan request for the KG-175 the appropriate NDA will have been established in Sweden to receive it.

Since the Internet was chosen as the preferred method, you have to use an encryption device compatible with the unicast packet protocol used by the Internet. The TACLANE is one of the devices compatible with the Internet. When using DIS as the interoperable protocol, which can be implemented using either broadcast or multicast, you have to install a process that converts the broadcast or multicast data into the unicast format. "In the old days," that had to be done by creating a locally grown software translator that ran on a separate workstation whose job was to pack and unpack DIS broadcast PDUs into unicast packets and vice versa that the Internet liked and the encryptor didn't reject as intrusion attempts (AFA 1999). Today, the newer classes

of routers can be programmed using scripts to accomplish that very function for you. They cost a bit more than regular routers, but they are the right engineering solution.

3.2 The Swedish Perspective

Since this is one of the first persistent, international, classified research projects conducted by FLSC in Stockholm, the authors felt it would be educational to describe in some detail how the processes work in Sweden in gaining permission to enter into such an agreement and to operate at the HEMLIG/Secret level. As stated earlier, two major areas of interest when operating in a coalition environment are:

- Information Security
- Communication Security

These implied tasks, which, by the way, are not specifically called out in Project Agreements, must be solved, as they are the enablers for the overall scope of the work to be done. The main problem is to solve the political, judicial and technical problems regarding electronic information exchange in systems containing and transmitting classified information. During this project FLSC has a mandate from the Swedish Government to share information up to and including HEMLIG/SECRET. The three areas to be described in general are:

- The Swedish Government's system for regulating the use of classified information
- Which information security activities must be accomplished to ensure compliance with Swedish laws and regulations
- The description of the approvals that FOI has to obtain to physically establish a communications link that can be used for IMTR

The basic principles of Swedish Judicial System are as follows. The Parliament is the legislative assembly of Sweden [5]. The Government is the executive branch of Swedish government. The Government is responsible to enforce the laws approved by the Parliament. This gives the Government the right to regulate the detailed application of the law according to the Swedish Constitution [6]. This is done by direct acts or regulations from the Government, or by instructions to Government Agencies to regulate within the realms of the Agencies or, in some cases, for the whole state sector. The Swedish Secrecy Law regulates how Government Agencies and individuals have to handle classified information in their everyday work. The Act is written in a general way, thus allowing the different Government Agencies to regulate the detailed handling of classified information. Some agencies, like the Swedish Armed Forces, regulate the use

of encryption within the whole Government/State sector; other rules are regulated locally by Government Agencies, such as FOI. These regulations are:

- Security Protection Law (1996:627)
- Personal Information Protection Law (1998:204)
- Information Secrecy Act (1980:657)
- Security Protection Act (1996:633)
- Swedish Armed Forces Regulation, Security Protection (FFS 2003:7)
- Swedish Armed Forces Regulation, COMSEC in Total Defence (FFS 1999:11)

This set is not a complete list of all the laws and regulations in the information and communication security area, but they are the most relevant ones. Some of the regulations are negotiable with the Agency that has the regulatory mandate from the Government. For example, the Swedish Armed Forces are allowed to decide that some regulations within its regulatory mandate don't have to be applied in certain cases. Usually these exemptions are a high-level decision by the Supreme Commander of the Swedish Armed Forces.

Some decisions have already been made regarding FOI and IMTR activities. The Government of Sweden (Ministry of Defence) has delegated to FOI, FLSC to share Swedish classified information up to and including HEMLIG/SECRET with a few limitations [7]. This is a necessary decision by the Government, thus enabling FOI, FLSC to share HEMLIG/SECRET information in line with Swedish law. Besides the principal approval of the Swedish Government, FOI, FLSC has to follow the

Swedish Secrecy Law [8], regulations from Government Agencies and FOI internal regulations regarding information and communication security. The FLSC simulators have to be documented regarding physical, logical and administrative security. Basically there are four main activities that are common for all aspects of security. They are:

- Analysis of the threat, threat probability and vulnerability in different system views
- Analysis of the information security classification and documentation of legal and regulatory security objectives
- Analysis of system compliance with security objectives
- Analyse security enhancements to system in different views, to enable a system-wide compliance with security objectives

The necessary system views are:

- Information
- Physical
- Logical
- Administrative

It is essential to analyze an FLSC simulator and its subcomponents for classified information and decide what information is releasable to the other party. Figure 3.1 illustrates the analysis and implementation process matrix used by FLSC.

	Threat/Probability/ Vulnerability	Security objectives	Security mechanisms
Physical	Physical analysis of site.	Legal and regulatory demands on site.	Comparison of objectives and analysis result. Implementation of security measures.
Logical	Logical analysis of site.	Legal and regulatory demands on site	Implementation of security measures.
Administrative	Information flow analysis.	Legal and regulatory demands on site	Implementation of security measures.

Figure 3.1. FLSC Information Security Analysis and Implementation Matrix.

The results of the information security activities must be documented and, in most cases, approved by proper authorities. Information classification and decisions regarding the release of classified information to a third

party is done by FLSC director. This activity can not be delegated below the director level at FOI. Figure 3.2 illustrates the level of approval needed for the various activities related to the appropriate security views.

	Threat/Probability/ Vulnerability	Security objectives	Security mechanisms
Physical	Documentation approved by FOI head of security.	Documentation approved by FOI head of security.	Approved by FOI head of security.
Logical	Documentation approved by FOI head of security.	Documentation approved by FOI head of security.	Possible implementation of security measures, described in MUST recommendations. System security accredited by MUST.
Administrative	Documents approved by FOI head of security in cooperation with FLSC director.	Documents approved by FOI head of security in cooperation with FLSC director.	Documents approved by FOI head of security in cooperation with FLSC director.

Figure 3.2. Approval Authority Matrix for FLSC.

The main point to consider concerning the different security views is that you may be able to solve a security issue with either an administrative, a logical/technical or physical method. It is important to get approvals from FLSC and FOI management for the selected courses of action regarding every security solution. In essence, management decisions are needed for approval of costs, workflow, and organizational and regulatory changes.

Communication security is viewed on a per activity basis because of each country's different regulations. In essence, the US part is regulated by NSA and the Swedish part is regulated by MUST/TSA. A commonly accepted policy for IMTR activities has to be established. At the moment this common ground can be established through the Swedish Materiel Administration (FMV). For Sweden, FOI writes a letter of request to FMV with a presentation of the project and the communication security needs for the project. From the US perspective, a request is made to the NSA and permission is granted to use US COMSEC equipment. As stated earlier, the first choice for communications security is to use a KG-175 TACLANE because the equipment already exists, but until final approval is granted, the status of the COMSEC equipment is pending.

4. Summary

After four years of conducting Coalition Mission Training Research, and four years of experience planning and executing the NATO's Exercise First WAVE, AFRL Mesa has gained valuable experience in how to plan and execute international research and development activities. They don't necessarily get any easier, but the past experience helps avoid making the same mistakes over

and over and identifies those processes previously not known that must be accomplished to do the job right. In addition, the CMTR trials and Exercise First WAVE shed new light on how important information and communications security is and, more specifically, how issues associated with those two areas require significant lead time to identify and then to solve. We have also learned that establishing high-fidelity simulation environments not only leads to the collection of credible research data, it provides invaluable training not otherwise available in a geo-politically constrained environment that augments most training programs if the technologies and methodologies are successfully transitioned. Finally, regardless of the number of times these multi-national and multi-site experiments are accomplished, new plateaus are reached and new horizons are imagined. We expect no less from the US-Sweden International Mission Training Research Project.

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International Mission Training Research (IMTR): Competency-Based Methods for Interoperable Training, Rehearsal and Evaluation

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ABSTRACT: *This paper describes a process to define the core knowledge, skills, and experiences required for successful mission performance in complex environments. This process, called the Mission Essential Competency (MEC) process includes a hierarchical decomposition and analysis of aircrew functions, skill and knowledge requirements, and developmental experiences required to build aircrew proficiency. MECs are structured descriptions of aircrew performance requirements in the combat environment. Various training methods and media are compared to identify those best able to provide the most important experiences and support the training requirements defined by current readiness and continuation training requirements. We will describe how MECs are being used to identify training gaps, define unique and common training objectives and scenario specifications, and specify metrics for training evaluation. The development of common definitions and specifications is a critical requirement to enhanced interoperability and data generalizability across mission areas and coalition training events. Example data and results from mission areas where the work has been completed will be provided and discussed. Finally, we will highlight how we are extending and generalizing the process with the Swedish Air Force Air Combat Simulation Centre (FLSC) to help define common mission training requirements for Peace Support Operations and interoperable distributed training and rehearsal events via International Mission Training Research (IMTR).*

1. Introduction

Organizations throughout the international simulation community have invested heavily in developing simulation environments aimed at providing a better user experience. One of the key issues that must be addressed is related to developing commonly defined requirements for the training to be accomplished with these environments. A related question is the degree of interoperability among definitional processes, and the nature of the actual requirements amongst international partners and collaborators working together on distributed simulation. Finally, assuming that we can define these requirements and develop scenarios and syllabi, what are the implications for routinely training, rehearsing, and evaluating coalition operations using the environments?

These questions have relevance for the more traditional mission areas of interest across coalition partner nations. However, an interesting question to be addressed is the extent to which we can answer these same questions for a new or emerging mission area, such as Peace Support Operations (PSO). This paper describes the process US Air Force Research Laboratory (AFRL) is implementing with researchers at FLSC and Subject Matter Expert (SME) pilots from the Swedish Air Force (SwAF), to examine and address the questions from the vantage of PSO and the integration of the SwAF into coalition operations in UN, NATO/OSCE (Organization for Security and Co-operation in Europe) and the European Union (EU).

Over the past few years researchers from the US Air Force, in collaboration with partner researchers from other countries, have conducted a series of applied examinations to determine: a) if common cross-country requirements can be defined and b) if those requirements are both palatable to the operational communities of interest and of use in driving training development and assessment, (including specifying important environmental fidelity characteristics for distributed simulation systems for training and rehearsal) [1]. The work has resulted in a substantive corpus of lessons learned and successes that are being used collectively to improve distributed simulation capabilities and the training and assessment that uses the capabilities [2] for all the partner nations.

2. Ongoing Research Explorations

As part of the research, a methodology has been developed called Mission Essential Competencies or

MECs. MECs are defined as the: “Higher-order individual, team, and inter-team competencies that a fully prepared pilot, crew or flight requires for successful mission completion under adverse conditions and in a non-permissive environment” [3] [4]. The MEC structure encompasses knowledge and skills (KS) and developmental experiences. The Warfighter Readiness Research Division of the AFRL has also developed a methodology to link these experiences to the KS they support and then directly to the higher level MEC [5]. Finally, field survey data from the MEC process is gathered from operators in each mission area. The data are summarized in a series of reports, and operational personnel review and interpret the data to identify training gaps and opportunities to address those gaps (including but not limited to increasing the application of high fidelity simulation).

We have demonstrated that MECs, the process, and the gap analyses generalize across many of the missions conducted in coalition operations that follow traditional doctrine and concepts of operation. Examples of these include air to air operations, air to ground/combat strike operations, air battle management, and most recently package commander operations. What we now know is that in a coalition distributed training event we can design, implement, and evaluate scenarios and syllabi that can be used by USAF or other nation crews with very little adjustment or refinement. The missions, the required knowledge and skills, and the developmental experiences necessary to achieve proficiency are easily transferable from one nation conducting that mission to another.

Moreover, the MEC definitions are being used as input to the simulator design and development process to ensure that the simulations that are developed and fielded are capable of supporting the training requirements and assessment needs identified with the MEC process.

3. Current research with the Swedish Air Force Air Combat Simulation Centre

The entire Swedish Armed Forces has over recent years undergone a major transformation, shifting in focus from defense against invasion to a defense with reactive units ready for deployment nationally or internationally. The extended international contribution by the Swedish Armed Forces is participation in multi-national PSO. As a partnership for peace member, this means that doctrines, procedures, equipment and education are adapting to support interoperability according to international

standards (i.e., UN, NATO/OSCE, EU). It is an ongoing process, but parts of the Swedish Armed Forces have been, currently are, or are ready to be deployed on multi-national PSO abroad.

Focusing on the SwAF fast-jet fighters (i.e., JAS 39 Gripen), there are currently four operational squadrons. The knowledge, skills and experiences within multi-national PSO varies among the individual pilots as well as the squadrons, with the highest mission readiness found at the SwAF Rapid Reaction Unit JAS 39 Gripen (SWAFRAP JAS 39) based at the F17 Blekinge Wing. SWAFRAP JAS 39 has a 30 day alert for deployment on international, multi-national PSO lead by UN, NATO/OSCE or EU. If deployed, they have a capability of staying on deployment for six months. After another 12 months they are ready for a new deployment.

The SwAF Gripens contribute as fighter or reconnaissance (limited) assets during international, multi-national PSO. The standard groupings are two-ships or four-ships of JAS 39 Gripens, but additional flight set-ups such as two-ships in Mixed Flight Force Operation four-ships (e.g., together with a two-ship of F-16) are also trained during international exercises. SWAFRAP JAS 39 use single-seat Gripens (currently edition A but eventually edition C) operationally, but there are two-seaters (currently edition B but eventually edition D) as well. The two-seaters are currently used for training but they might be used for other purposes in the future.

The PSO mission area that SWAFRAP JAS 39 currently contributes to internationally is Air Defense (AD) and that is also the focus of the first MEC-process conducted within the IMTR-project. The specific PSO AD mission types for which the SWAFRAP JAS 39 has been training are Combat Air Patrol, Sweeps, Escorts, and Offensive Counter Air (lead for fighter assets in Composite Air Operations). These are the PSO AD mission areas where SwAF pilots have the highest mission readiness, but other areas (e.g., Air-to-Surface) might be implemented in the future. Large-scale scenario training for PSO AD missions is conducted during various kinds of distributed simulation exercises at FLSC and at live exercises (squadron, national and international level).

There are several objectives for conducting a MEC-process for SwAF PSO AD within the IMTR project. As stated, the ongoing transformation from defense against invasion to reactive defense units with an international emphasis has been and still is a great challenge in many ways. For the SwAF this has meant new demands on the

equipment; but of even higher interest in this case is the demand on the pilots' competencies. They should no longer only be ready to perform their missions according to Swedish procedures but to perform them in another way, in new geographical areas according to other procedures and in co-operation with other nations.

Concerning SwAF PSO AD simulator training, FLSC has for the last couple of years provided an extensive training program focused on developing these emerging, additional competencies among the pilots. Most pilots at the SwAF operational and training squadrons have experienced the training at FLSC, and many of them have also gone through extensive training for multi-national PSO AD at live exercises. To enhance training in the future, there is a need to establish the core knowledge, skills, and developmental experiences identified as vital for full mission readiness by SME pilots, and to feed that back to the continuous evaluation and development of the training and research program.

Collaboration with other nations on international mission training research, will add great value to the process of maximizing interoperability via enhanced individual, team, and inter-team training on a national and international level. Distributed simulation exercises with other nations, using scenarios that are tailored according to the MEC-processes for the pilots of each nation, is a very promising way of reaching this goal. The rationale is that scenarios created to support the development of knowledge, skills, and experiences identified as important for the US and Swedish pilots respectively will strongly contribute to enhanced mission readiness and interoperability in multi-national operations. Another important benefit of this collaboration is the fact that well defined individual, team and inter-team competencies as well as skills and procedures will be of great support when validating operational units before deploying them into the multi-national arena.

4. Conclusions

There is considerable potential and a growing body of evidence to suggest that tremendous efficiencies can be gained in coalition mission training research and applications through the development and institutionalization of common approaches to defining requirements, driving scenarios and instructional events, and assessing the impact of the training. Further, the effectiveness of what we hope will become routine distributed training and rehearsal events at the coalition

level will substantially improve shared understanding of training environment capabilities, mission and training objectives, and metrics for quantifying impacts and return on national investment. "Train as we fight" will only be successful if we realize the mutual and multinational benefits of shared research, application, and operations.

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